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Clinical Overview of Radon

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This presentation is designed by the Agency for Toxic Substances and Disease Registry or ATSDR, to familiarize health care providers about the potential health effects of exposure to elevated levels of radon, provide guidance in areas of clinical evaluation and patient management; and share exposure prevention strategies for patients.

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By the end of this presentation participants will be able to define radon and describe its sources and routes of exposure, explain potential health effects of exposure to elevated levels of radon, and describe how to evaluate and treat patients, as well as how to prevent exposure to radon.

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To begin, we will discuss properties of radon.

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Radon is a chemically and biologically inert noble gas produced when naturally occurring uranium and thorium in rock, soil, water, and air undergo radioactive decay. Radon undergoes further radioactive decay into daughters or progeny until reaching a stable form of lead.

Two isotopes of radon, radon two twenty and radon two twenty-two, are the daughters in two decay chains that begin with naturally occurring thorium two thirty-two and uranium two thirty-eight, respectively.

Radon in this presentation will refer to radon two twenty-two and its progeny. It has a half-life of three point eight days and is a colorless, heavy, odorless gas that is imperceptible to the senses.

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We will now discuss sources of radon in the environment.

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Uranium and thorium are ubiquitous in the earth's crust, and rock and soil will continually release radon in the environment. Radon gas in rocks and soil can move to air, groundwater, and surface water. Radon is present in building materials, and the burning of coal and other fossil fuels also releases radon. When radon escapes from soil or is discharged from emission stacks to the outdoor air, it is diluted to levels that are normally lower than indoor air.

The main source of indoor radon gas is from rock and soil underneath buildings where it infiltrates through crawl spaces; cracks in solid floors and walls; construction joints; gaps in suspended floors and around service pipes; and cavities inside walls. Radon may also enter dwellings through the water supply and natural gas previously in contact with underground uranium and thorium-bearing rock and soil.

The radioactive radon attaches to dust particles, smoke, walls, floors, ventilation equipment, and clothing, allowing it to be inhaled into the lungs.

Regardless of where you live, you can have elevated levels of radon inside your dwelling.

Exposure to high concentrations of radon can also occur in any location with geologic radon sources. These sources can include underground uranium, hard rock and vanadium *(va-nay-di-um)* mines, and water treatment plants. Radioactively contaminated sites can include uranium mill sites and associated mill tailing piles, phosphate fertilizer plants, oil refineries, power plants, and piping facilities for natural gas and oil. Locations that are not contaminated, but at which elevated natural radon levels exist, can include utility and subway tunnels, fish hatcheries, natural caverns, and excavation sites.

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Background levels of radon in outdoor air are generally quite low, typically around zero point four picocuries *(pee-co-cure-ees)* per liter of air. These levels can vary based on location and the geology of the soil.

The average indoor level in the U.S. is 1.25 *(one point two five)* picocuries *(pee-co-cure-ees)* per liter. In indoor locations, such as dwellings, schools, or office buildings, levels of radon are generally higher than outdoor levels. This is especially true with newer construction that is more energy efficient as it can increase levels of radon inside. Basements and lower levels of buildings are likely to have higher levels of radon, as it is a heavy gas.

The action level recommended by the Environmental Protection Agency, or E-P-A, for indoor exposure to radon is four picocuries *(pee-co-cure-ees)* per liter. Nearly one out of every fifteen dwellings in the U.S. is estimated to have elevated radon levels at or above EPA's action level.

The American Cancer Society estimated that there are eight million dwellings in the U.S. with elevated levels of radon. The EPA and the U. S. Surgeon General recommend testing all dwellings below the third floor for radon.

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Next, we will cover routes of exposure to radon.

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Exposure to a substance can occur by inhalation, ingestion, or dermal contact. The exposure may be short-term, intermediate, or long-term.

Everyone is potentially exposed to environmental radon. However, only those people in environments with increased levels of radon are at a higher risk of potentially developing negative health effects.

The toxic effects of radon depend on several factors. These factors can include the concentration, duration, and frequency of exposure. Exposure is determined by assessing potential exposure pathways, including potential sources and routes of exposure.  Other risk factors should be considered when assessing exposure, such as a history of smoking, and individual characteristics such as age, genetic factors, and health status.

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The most important route of exposure to radon is inhalation. Radon may be released into the indoor environment in several ways. There may be infiltration of radon from soil into buildings, or release of radon from water into the air when washing clothes and dishes, flushing toilets, and showering. There may also be release of radon from household appliances that are not properly vented to the outside.

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Exposure to radon through ingestion can occur as a result of radon gas dissolving in drinking water. Water that contacts rocks and soil will contain dissolved radon. As such, in most drinking water, radon is naturally present. Some radon swallowed in drinking water passes through the stomach walls and intestine into the bloodstream. After radon reaches the lungs, it is readily breathed out through the pulmonary circulation. Therefore, ingestion is a minimal exposure route.

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Data are very limited regarding the absorption of radon following dermal exposure and this is not considered a significant exposure route.

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Now, we will highlight the populations at risk.

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There are two general populations at risk for radon exposure:

Those who live

and those who work in environments with elevated radon levels.

Of the individuals that live in dwellings with elevated radon levels, there are some populations at special risk. Children exposed to radon may have higher estimated radiation doses than adults related to the difference in a child's lung size, higher minute *(min-ute)* volume, and faster respiration rate. It should be noted that radon exposures during childhood may not show up as health effects until adulthood.

Others at special risk include people who smoke and everyone living in smoking households.

The risk of lung cancer from radon exposure is estimated to be ten to twenty times greater for persons who smoke cigarettes in comparison with those who have never smoked. Tobacco has elevated levels of radon daughters attached to its leaves, mostly Polonium *(poll-**oh**-nee-um)* two ten and Lead two ten. There is a synergistic effect between the alpha radiation of the radon daughters with the radiation emitted by tobacco when it burns and smoke is inhaled.

Finally, people who have chronic respiratory disease, such as asthma, emphysema, or fibrosis are also at risk. These individuals often have reduced expiration efficiency and increased residual volume, in other words, greater than normal amounts of air left in the lungs after normal expiration, which can increase the amount of time that radon daughters remain in the lungs.

People who work in environments with elevated radon levels are also at special risk. These groups include,

Miners, with additive effects of cigarette smoke for lung cancer among miners exposed to radon,

Radon mitigation professionals,

Scientists studying radon or other radionuclides *(ray-dee-oh-new-clides),*

Workers in water treatment plants,

Persons who study or explore caves (also known as speleologists *(spee-lee-olo-gists),* and

Fish hatchery and farm workers.

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Next, we will discuss the potential health effects of elevated radon exposure.

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The primary adverse health effect of exposure to increased levels of radon is lung cancer, which may take years to develop. The high-energy alpha emissions from radon daughters deposited in the airways are the primary cause of toxicity concern.

Cigarette smoking is the number one cause of lung cancer with radon gas exposure being the second leading cause. Exposure to elevated levels of radon gas is estimated to account for about twenty-one thousand lung cancer deaths in the U.S. every year. The World Health Organization or W-H-O estimates that radon causes between 6% *(six percent)* and 15% *(fifteen percent)* of all lung cancers worldwide. For people who smoke, exposure to elevated radon levels increases their already heightened lung cancer risk.

Epidemiologic studies of miner cohorts have reported increased frequencies of chronic, nonmalignant lung diseases as well as emphysema, chronic interstitial pneumonia, and pulmonary fibrosis. The risk of these diseases developing increases as cumulative exposure to radiation from radon daughters and cigarette smoking increases.

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The sequence of events leading from irradiation of living cells is generally believed to involve ionization of atoms in D-N-A. Ionizing radiation can cause genetic instability through D-N-A breaks, gene mutations, and inaccurate cell repair.

The main health problems from radon exposure arise when radon daughters attached to dust or smoke particles, termed the attached fraction, is inhaled. Once inhaled, these particles deposit in the airway, particularly the tracheobronchial tree, and irradiate nearby cells repetitively with alpha particles as each radon daughter atom transforms through the decay chain. These alpha particles can deliver a large, localized radiation dose.

Smoking and other aerosol-generating activities, for example, vacuuming, cooking, and use of wood burning fireplaces and circulating fans, will increase the exposure. The air in homes with wood burning fireplaces and stoves is comparable in quality to that of mines. Radon exposure is much higher in dwellings of people who smoke relative to those who do not smoke. Exposures are also higher in dusty mines relative to well ventilated ones.

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Now that we have discussed sources of radon, routes of exposure, and health effects, we will discuss aspects of clinical evaluation.

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Patients with potential exposure to increased radon levels should undergo a thorough medical evaluation that includes a detailed occupational and environmental exposure history, a physical exam that targets respiratory complaints, and appropriate imaging and lab testing as part of the differential diagnosis.

The initial interview should document the patient's:

Past medical history, including history of lung disease,

Current respiratory and other health symptoms and

Smoking history.

Additionally, a detailed exposure history should be gathered, focusing on potential occupational and environmental exposures. The occupational history should include questions about:

Any work in occupations with a high risk for elevated radon level exposure or exposure to other sources of ionizing radiation, The source and concentration of radon exposure, if known, as well as the duration, which allows estimation of the total radiation dose,

Whether any protective equipment was used,

And questions about any other chemical exposures that may have occurred.

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The other part of an exposure history explores potential environmental exposures and includes questions about:

Whether there was any known direct contact with elevated radon,

Results of any radon testing done in the patient's dwelling over the past twenty years,

Characteristics of the dwelling, such as whether the foundation was built on a slab or crawl space, and whether there is a finished or unfinished basement,

The amount of time the patient spends in the basement or lower level of the dwelling,

Ventilation of the dwelling, for example whether the patient frequently opens the windows,

Energy-efficiency characteristics of the dwelling, as tightly sealed buildings keep radon inside,

The number and type of gas appliances used in the dwelling and whether these are vented to the outside; or have double wall vent pipes to help identify improperly vented gas-fed stoves and fireplaces, gas dryers, and water heaters;

Whether the source of water is a private well or a public water system, as water from public water systems is likely to stand in a reservoir for several days and be spray oxygenated, allowing it to release radon before it reaches the dwelling,

Whether there are people who smoke in the dwelling and

Similar details about past residences.

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When evaluating a radon exposed patient, pay particular attention to the lungs on physical, as these are most likely to be affected by radon exposure.

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The decision to perform diagnostic tests should be based on the patient's history and clinical evaluation, weighing possible risks and benefits of testing.

Radon air testing can be used as a proxy for exposure, and if there is concern, there are three tests that can be used to assess for lung disease.

The first is a simple Pulmonary Function Test, P-F-T or Spirometry *(spy-rom-eh-tree)*.

Another test is a chest x-ray.

Finally, a low-dose C-T may be considered.

It should be remembered that radiological changes from exposure to elevated radon levels are not typically evident until after many years, sometimes decades after the long-term exposure.

Currently, no effective community-wide screening methods are available for medical prevention or early diagnosis and treatment of lung disease due to elevated levels of radon once exposure has occurred.

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Next, we will describe treatment and management of patients exposed to elevated levels of radon.

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In general, there is no specific treatment for radon exposure. Treatment of lung disease is indicated based on the specific problem encountered.

Most radon daughters decay via alpha or beta emission with half-lives so short that methods for reducing toxicity would be ineffective.

The key to management is to help patients recognize the importance of getting their home tested for radon, so that measures can be taken to reduce exposure and risk of lung cancer.

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Patients who have been exposed to elevated levels of radon may need outpatient follow-up. Periodic clinical evaluations may detect abnormalities at an early stage if they occur. Further testing may be performed based on symptoms, physical exam findings, and standard clinical practice.

Screening for lung cancer should be done in accordance with the recommendations of the U.S. Preventive Services Task Force or U-S-P-S-T-F, based on the patient’s age, gender, and other risk factors.

It is important to assist patients who smoke with a plan to quit.

When treating a radon exposed patient, consider consultation with a specialist such as an occupational and environmental medicine physician who can assist with development of a periodic monitoring plan, as appropriate.

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Now we will turn to counseling of radon exposed patients and discuss risk reduction strategies.

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Patients identified as having exposures to elevated levels of radon should be informed of the potential risk of disease, and especially the interaction between smoking and radon exposure increasing the risk of lung cancer.

Advise patients that testing a dwelling for elevated radon levels is the only effective way to find out if it has a radon problem. If renting or purchasing a dwelling, it is recommended to request a radon test or results of previous testing.

Ventilating the dwelling is a great way to decrease indoor pollutants, including radon, but it is a temporary measure which is dependent on the weather.

Remind patients that the benefits of reducing elevated radon levels through remediation outweigh the costs.

It is also important to emphasize that stopping smoking in the dwelling may greatly reduce the possibility of lung disease among those living in it. Smoking cessation reduces the radiation dose from radon, since the presence of smoke particles increases the radiation dose from radon daughters. This risk reduction strategy is of particular importance for children as the risk of lung cancer for children co-exposed to tobacco smoke and high levels of radon is much greater than children exposed to high levels of radon alone.

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Ask your patients if they have tested their dwelling for radon. If they have not, urge them to do so. Radon testing is the most important measure to identify if a dwelling has elevated levels of radon.

Short-term and long-term tests, lasting a few days to several months, are available to identify whether there are increased levels of radon gas in the dwelling. Short-term testing is the quickest way to determine the presence of a potential problem, but it is the least accurate for determining long-term exposure. Do-it-yourself short-term testing kits are typically available at local hardware stores.

Testing should be conducted in the lowest-inhabited area of the dwelling keeping doors and windows shut, allowing very brief periods to open doors when entering or leaving the dwelling. The test units should be placed away from windows, doors, and vents, and all written testing instructions should be followed to help ensure accuracy.

Retesting a dwelling after doing renovations is important since renovations may result in increasing radon levels.

If patients need more information, you may direct them to the National Radon Hotline at one eight hundred five five seven two three six six. This hotline is operated by Kansas State University in partnership with the E-P-A where callers can speak with a radon technical specialist or be directed to their state radon program.

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If an elevated level of radon is found in the patient's home, there are ways to reduce radon exposure.

Radon reduction or remediation uses methods to reduce radon concentrations to below the EPA recommended action level of four picocuries *(pee-co-cure-ees)* per liter, using active soil depressurization, or A-S-D, in existing dwellings. A-S-D can also be built in new dwellings as a proactive measure to prevent elevated levels of radon indoors.

Active soil subslab depressurization with suction lowers the soil pressure below that inside the dwelling and prevents inward soil gas migration. Pipes, attached to a suction fan, are inserted into the ground below the basement floor, creating a low-pressure region under the dwelling. This depressurization is one of the most effective methods of lowering radon levels in many dwellings and can reduce indoor radon levels by as much as ninety nine percent.

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We will now summarize the important takeaways from this presentation.

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Many people are exposed to elevated levels of radon indoors.

Exposure to elevated levels of radon is the second leading cause of lung cancer.

Smoking increases radon exposure.

Testing and remediation as needed can decrease exposures to elevated levels of radon.

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There are many additional resources for information on radon which are listed on the next two slides.